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Abstract: Gold mineralization at Doris North is hosted in a conformable succession of mafic volcanic and gabbroic rocks that are folded into a tight, shallowly north-plunging antiform. Mineralization is invariably hosted in continuous white quartz veins displaying semiregular sericite and tourmaline-rich septa. A hydrothermal alteration assemblage of iron dolomite, sericite, paragonite, and pyrite overprints mafic volcanic and gabbroic host rocks. Three significant, north-trending vein systems are known: West Valley Wall, Central, and Lakeshore veins. The Hinge zone occurs where the Central and Lakeshore veins merge. The overall geometry of the vein systems closely mimics the regional antiformal fold geometry in basaltic and gabbroic rocks. Textural relationships are consistent with vein emplacement along structural weaknesses created by pre-existing or developing fold structures.

Résumé : La minéralisation aurifère au gîte de Doris North est encaissée dans une succession de roches volcaniques mafiques et de roches gabbroïques concordantes, plissée en un antiforme serré à axe plongeant faiblement vers le nord. La minéralisation est invariablement contenue dans des filons continus de quartz blanc qui présentent des cloisons semi-régulières riches en séricite et en tourmaline. Une association de minéraux d'altération hydrothermale (dolomite ferrifère, séricite, paragonite et pyrite) se superpose aux roches volcaniques mafiques et aux roches gabbroïques qui encaissent les filons. Trois importants systèmes filoniens de direction nord ont été identifiés : les filons West Valley Wall, Central et Lakeshore. La zone Hinge se trouve à la convergence des systèmes Central et Lakeshore. La géométrie globale des systèmes filoniens correspond étroitement à la géométrie régionale de la structure antiforme dans les roches basaltiques et gabbroïques. Les relations texturales sont compatibles avec une mise en place des filons le long de faiblesses structurales engendrées par des structures plissées pré-existantes ou en voie de formation.

INTRODUCTION

Significant discoveries of gold mineralization have been made in the Hope Bay volcanic belt over the past decade, with important occurrences including the Boston, Doris, and Madrid group of deposits. The Doris North area has been the focus of recent exploration activity and is currently undergoing a feasibility study conducted by owner Miramar Mining Corp. An updated resource calculation for the Doris North area is 458 200 tonnes grading 22.0 g/t Au, yielding a total indicated and inferred resource of 323 900 ounces of gold (Miramar Mining Corp, press release, September 10, 2002). Advanced exploration activities at Doris North have resulted in an extensive database of closely spaced drillhole data, providing an excellent opportunity to study critical deposit-scale features that are important to mine development and exploration.

This report gives results of detailed core logging of representative sections through Doris North, complemented by detailed surface mapping. Emphasis was placed on describing stratigraphic, structural, and alteration characteristics of gold mineralization. This study forms part of a larger, multiyear, collaborative study of the setting and nature of gold mineralization in the northern Hope Bay belt that involves Miramar Mining Corp. (including the former Hope Bay Gold Corp.), the Canada-Nunavut Geoscience Office, and Indian and Northern Affairs Canada.

HISTORY OF GOLD EXPLORATION

Initial gold exploration by BHP Minerals Canada Ltd. (now BHP-Billiton Inc.) in the Hope Bay belt from the late 1980s until 1999 resulted in the discovery of the Boston (in 1991), Madrid (in 1993) and Doris (in 1995) deposits. BHP spent over CDN$85 million, conducted over 115 000 m of diamond drilling, and drove a decline at Boston in order to extract a 26 761 tonne bulk sample there (J.S. Gebert, unpub. rept., 1999). In late 1999, Cambiex Exploration Inc. (later Hope Bay Gold Corp.) acquired BHP's interest in the belt and entered into a 50:50 joint venture with Miramar Mining Corp. In 2000, the Hope Bay joint venture concentrated on infill drilling at the Boston and Doris deposits, with some surface grassroots exploration and drilling in the summer that resulted in the discovery of the Naartok and Suluk deposits in the Madrid area in 2001. In the spring of 2002, Hope Bay Gold merged with Miramar, giving Miramar 100% interest in the Hope Bay project. In 2002, an infill drill program was completed on the Doris Hinge area that provided information necessary to complete a feasibility study. Additional surface mapping and sampling with drilling occurred throughout the summer.

GEOLOGY OF THE HOPE BAY VOLCANIC BELT

The Hope Bay volcanic belt is an Archean greenstone belt located in the northeast part of the Slave Structural Province (Fig. 1). Current understanding of the geology of the Hope Bay belt is based on previous government mapping, including Fraser (1964), Gibbons (1987), Gebert (1990, 1993) and various unpublished company reports and graduate theses from BHP and Miramar. Detailed mapping by Sherlock et al. (2003) covered the northern part of the belt, including Doris North (Fig. 1). The Hope Bay belt extends north-south for about 80 km and is 7 to 15 km wide (Fig. 1). Stratigraphy generally strikes north-south (belt-parallel) and consists of mafic volcanic rocks, intermediate to felsic volcanic rocks, and lesser sedimentary and ultramafic rocks. Mafic volcanic rocks dominate the eastern portion of the belt, but rock types in the western part of the belt are more varied, including felsic volcanic rocks and siliciclastic sedimentary rocks. Uranium-lead geochronology indicates that felsic volcanism spanned an interval of at least 53 Ma (2716–2663 Ma; Hebel, 1999; M.U. Hebel and J.K. Mortensen, unpub. data, 2001). Archean intrusive rocks are minor and comprise ultramafic, gabbro, and quartz-feldspar porphyry dykes and sills, and syenite plugs (J.S. Gebert, unpub. rept., 1999). Undeformed and unmetamorphosed Neoproterozoic diabase sills and dykes of the 723 +4/–2 Ma Franklin Igneous Events (Heaman et al., 1992) are common in the northern part of the belt and can typically be traced for several kilometres. Contact metamorphic effects are noticeable for up to 20 m in neighbouring rocks.

To the east, the Hope Bay belt is bounded by felsic intrusions that separate it from the Elu Inlet volcanic belt (Fig. 1). A granodiorite northeast of the Hope Bay belt gave a U-Pb zircon age of 2672 +4/–1 Ma, suggesting a syn- to late-volcanic age of emplacement (Bevier and Gebert, 1991). The southeastern margin of the Hope Bay belt is a heterogeneous gneiss terrane that yielded a U-Pb zircon age of 2649.5 +2.9/–2.5 Ma and a titanite age of 2589 Ma, which may represent a metamorphic age (Hebel, 1999; M.U. Hebel and J.K. Mortensen, unpub. data, 2001). The Hope Bay belt is bordered to the west by plutonic rocks that contain foliated mafic fragments dated at 2608 Ma, placing a lower limit on deformation and metamorphism (Bevier and Gebert, 1991). Metamorphic grade is lower greenschist facies in the interior of the belt (including Doris North) and amphibolite facies near the belt margins.

LOCAL GEOLOGY

The regional geology of the northern portion of the Hope Bay volcanic belt is described in a companion paper (Sherlock et al., 2003). The focus of this contribution is the stratigraphy and alteration of the Doris deposit.

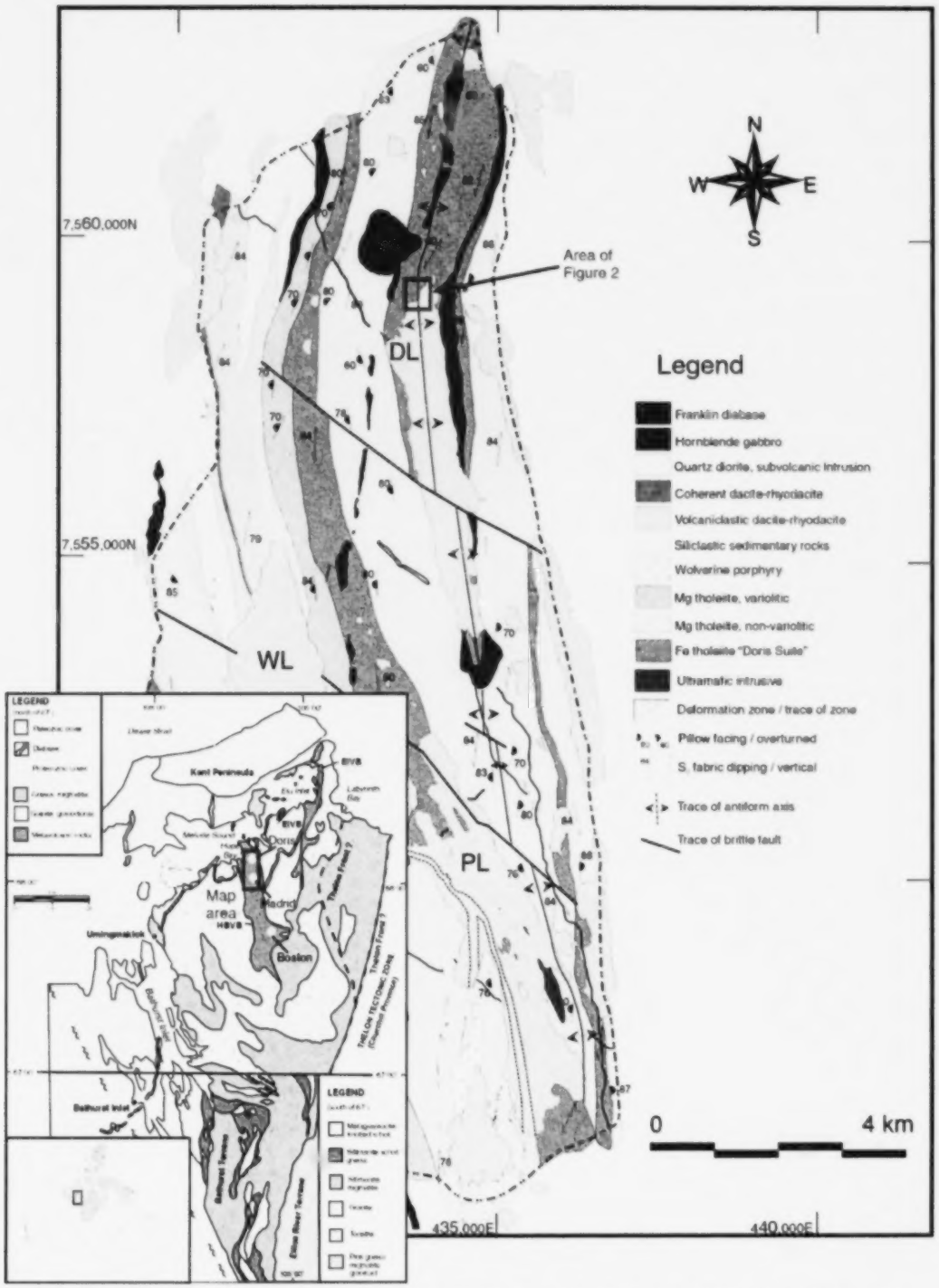
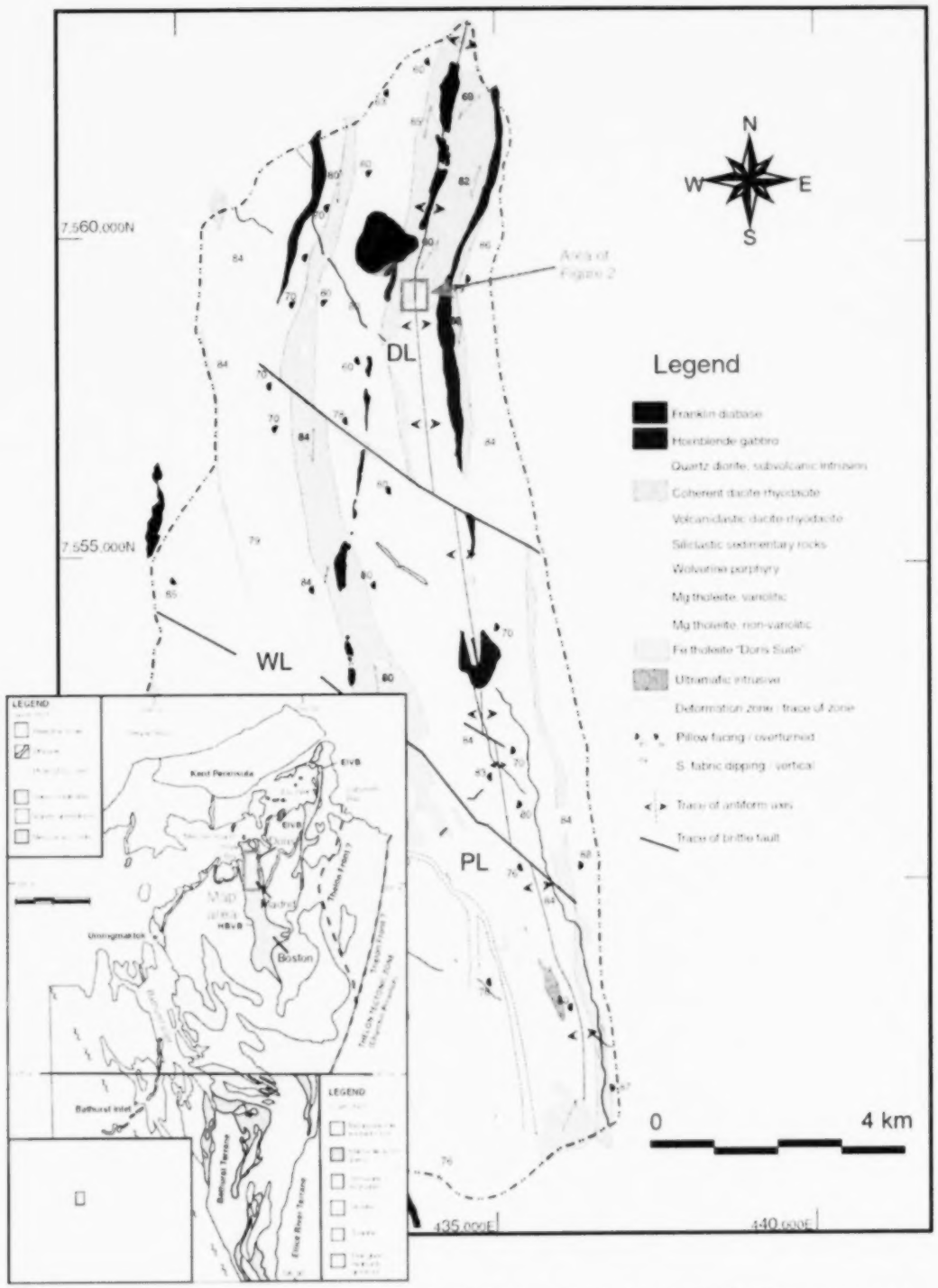


Figure 1. *Geology of the Hope Bay volcanic belt (HBVB;* from *Sherlock et al., 2003). Abbreviations: DL, Doris lake; WL, Windy lake; PL, Patch lake. Inset is the generalized geology of the Bathurst Block. Geology north of latitude 67°N* modified from *Fraser (1964); geology south of latitude 67°N* modified from *Thompson et al. (1986) and Gebert (1993). The Hope Bay volcanic belt (HBVB) and adjacent Elu Inlet volcanic belt (EIVB) are indicated.*



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An approximately 500 m wide, wedge-shaped, north-striking package of mafic volcanic rocks, known as the 'Doris Suite' basalt, underlies the Doris deposits (Fig. 1). These rocks are exposed mainly on the north shore of Doris lake, extending north towards the Arctic Ocean. The Doris Suite consists of a conformable succession of dark-coloured, variably magnetic, vesicular-amygdaloidal, massive and pillowed basalt folded around a central gabbro-textured rock (Fig. 2, 3). Based on geochemical data, these volcanic rocks are Fe tholeiite. The Fe tholeiite is bounded by a visually distinct and nonmagnetic package of Mg tholeiite (Fig. 2; Sherlock et al., 2002, 2003). A magnetic susceptibility metre was used extensively during mapping and core logging to distinguish otherwise visually similar rock units.

Rock types

Vesicular-amygdaloidal basalt is the most areally extensive unit present at Doris North (Fig. 2, 3). Amygdules are typically weathered out on surface exposures, leaving a distinctive pitted texture, with rounded to flattened pits ranging from 0.1 to 4 cm across and averaging 1 cm (Fig. 4A, B). Narrow

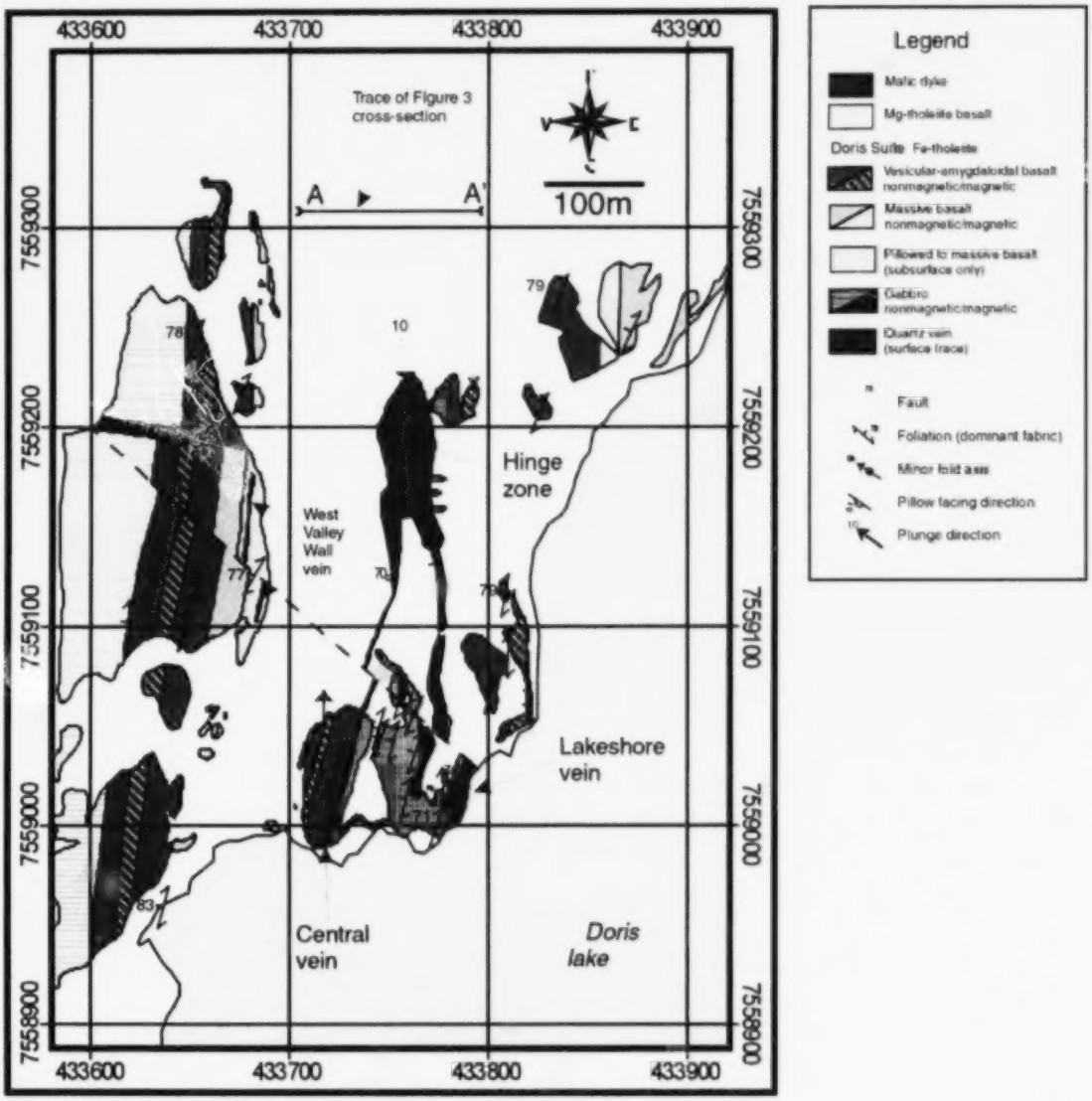


Figure 2. *Geology of the Doris North area.*

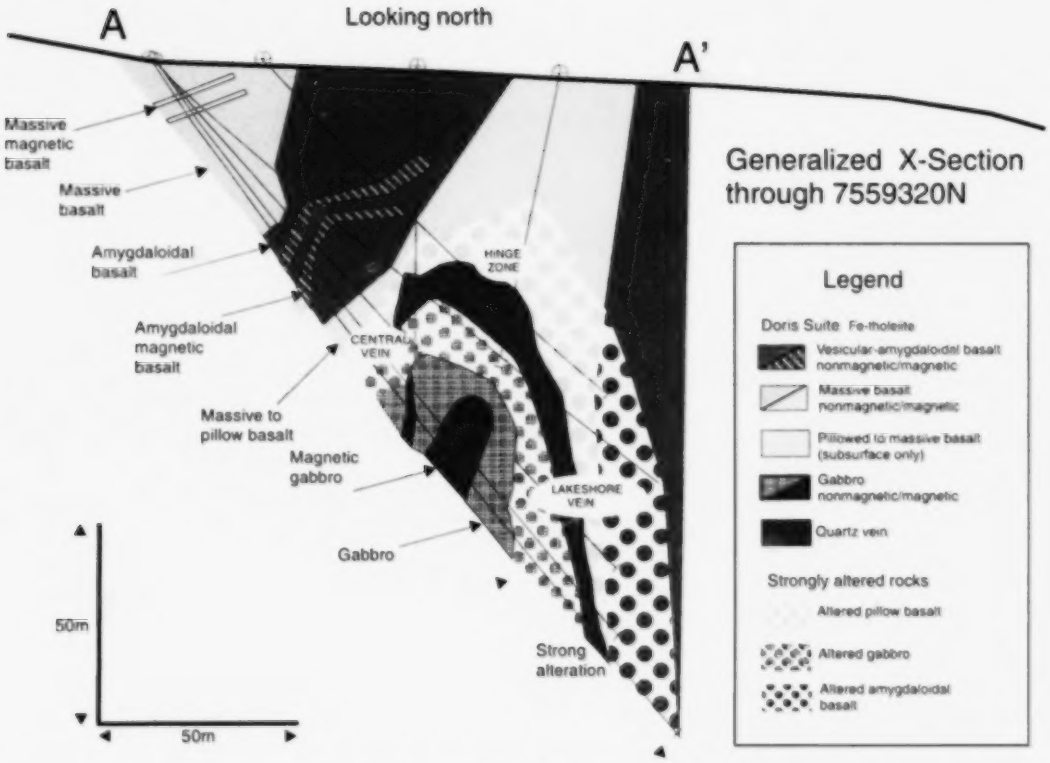


Figure 3. *Idealized cross-section through Doris North at 7559320N* (see *Fig. 2 for location of section).*

(<2 cm wide) chloritic pillow rinds are observed in outcrop; however, classic pillow forms are poorly preserved. Pillow rinds may be observed in drill core (Fig. 4C). Fine-grained amygdules can be confused with co-existing varioles, which are uniformly less than 1 cm, oblate shaped, and typically coalesce in centimetre- to fist-sized masses (Fig. 4C). Magnetic and nonmagnetic vesicular-amygdaloidal rocks are typically interbedded. Magnetic intervals can be up to several metres wide and consist of massive and fine-grained rocks that lack pillows. Magnetic susceptibility is highest in the centre of these units and generally decreases steadily towards both margins.

Massive basalt is characterized by fine-grained even texture that lacks identifiable volcanic features such as amygdules or pillows (Fig. 2, 3). Intervals of massive basalt are interbedded with vesicular-amygdaloidal basalt, although distinct contacts between these units are rare. Locally developed millimetre- to centimetre-scale banded textures are common and likely formed as a result of later structural overprinting. Magnetic and nonmagnetic units are recognized: magnetic varieties are commonly darker in colour and contain more abundant calcite stringers than nonmagnetic varieties. These calcite stringers locally remobilized magnetite from the surrounding basalt.

A visually distinct interval of pillowed to massive basalt is characterized by abundant, well formed pillow rinds and a lack of amygdules and varioles (Fig. 3). Pillow rinds in this unit are typically more abundant and thicker than those in vesicular-amygdaloidal basalt. Volcanic textures such as hyaloclastite and pillow breccia are common. This unit has so far been identified only in drill core.

Fine- to medium-grained, equigranular gabbro is present in the core region of Doris North (Fig. 2 and 3). Grain size is generally finest near the gabbro margins and gradually coarsens towards the interior (Fig. 4D). Rare pillow basalt in the core of this unit suggests that the gabbro is actually a coarse basaltic flow conformable with stratigraphy, rather than an intrusive body. Magnetic and nonmagnetic varieties are recognized: the magnetic gabbro is distinguished by high magnetite and hematite contents, and the nonmagnetic gabbro contains sparse magnetite and abundant leucoxene. Late mafic dykes locally crosscut stratigraphy and are coarser grained and more leucocratic than the conformable gabbro described above (Fig. 2).

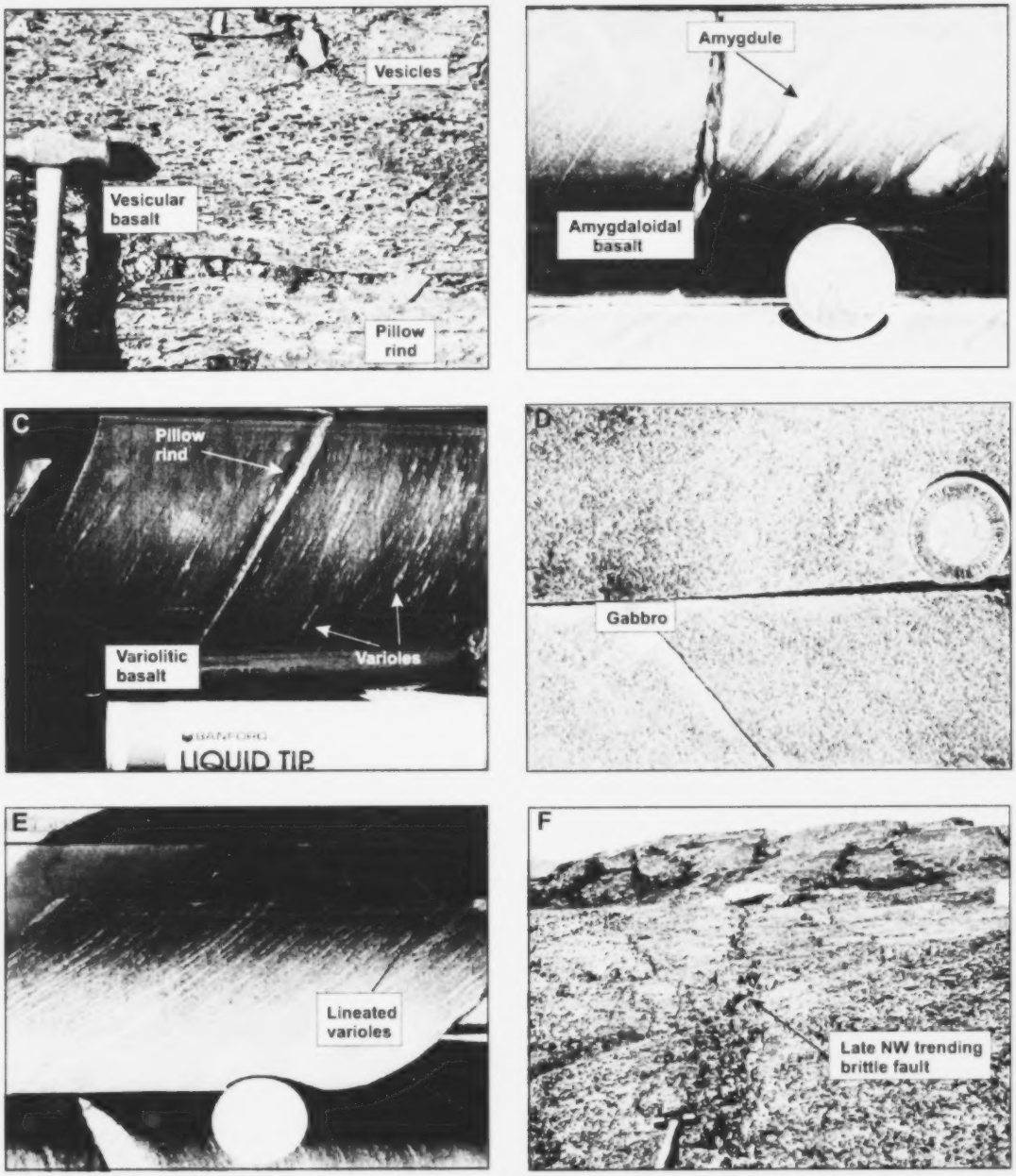


Figure 4. *Rock types and structure: **A)** vesicular-amygdaloidal basalt, hammer for scale. **B)** large amygdules with symmetrical pressure shadows in vesicular-amygdaloidal basalt; coin for scale. **C)** narrow chloritic pillow rind and fine varioles in basalt; felt marker for scale; **D)** gabbro; coin for scale. **E)** strongly lineated varioles in basalt, producing an apparent compositional banding; coin for scale; **F)** northwest-trending vertical brittle fault; hammer for scale.*

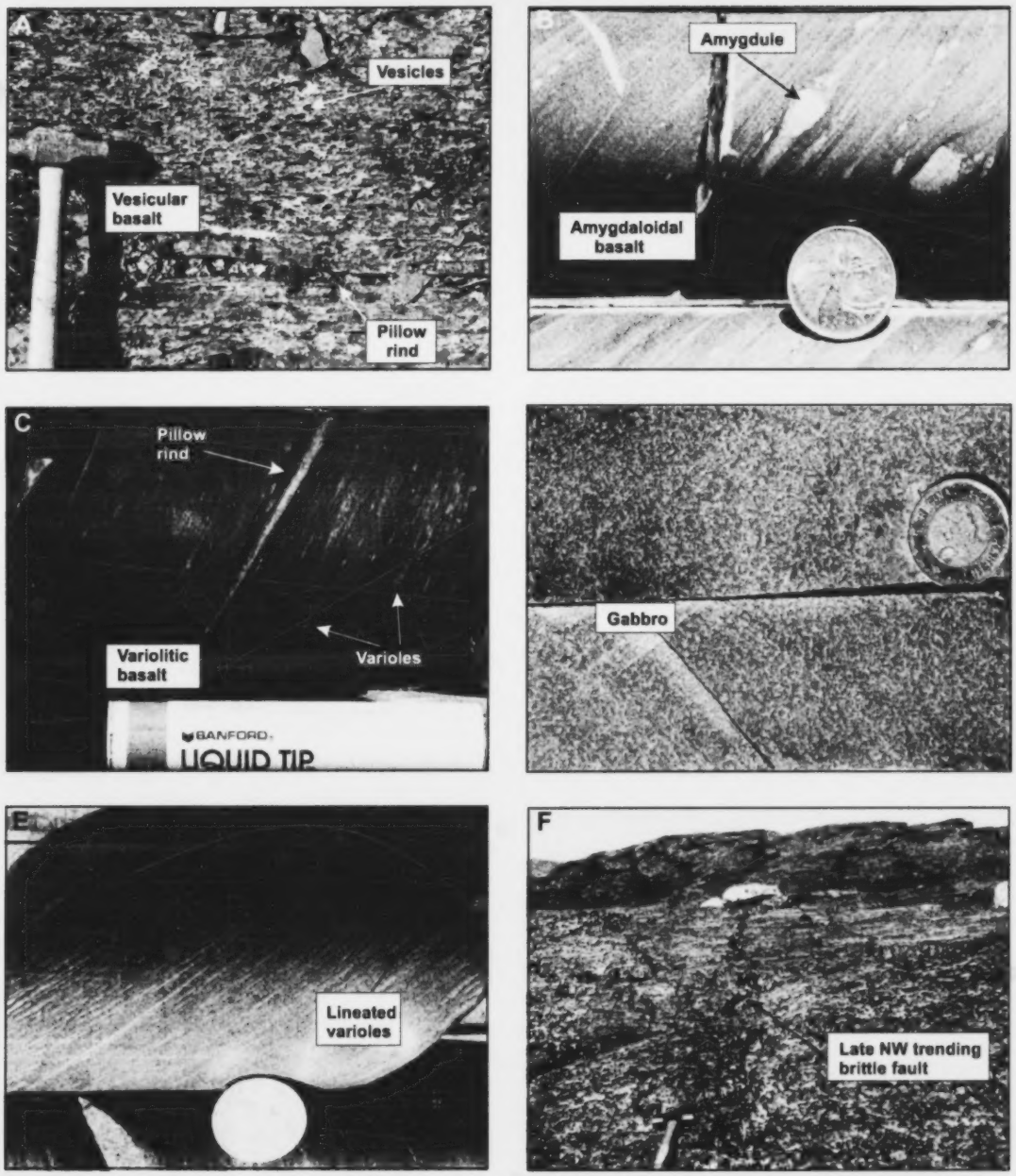


Figure 4. *Rock types and structure:* ***A)*** *vesicular-amygdaloidal basalt; hammer for scale;* ***B)*** *large amygdules with symmetrical pressure shadows in vesicular-amygdaloidal basalt; coin for scale;* ***C)*** *narrow chloritic pillow rind and fine varioles in basalt; felt marker for scale;* ***D)*** *gabbro; coin for scale;* ***E)*** *strongly lineated varioles in basalt, producing an apparent compositional banding; coin for scale;* ***F)*** *northwest-trending vertical brittle fault; hammer for scale.*

Structural geology

Stratigraphy is north striking, based on the correlation of rock units on surface and in drill core. All basaltic and gabbroic rocks have been affected by a penetrative foliation that trends approximately 185° and dips steeply (70–80°) to the west. This fabric is the regional S_2 fabric of Sherlock et al. (2002, 2003). In the least-altered rock types, foliation is defined by chlorite and altered rocks form paragonite schist. Pillow rinds are typically flattened and transposed into foliation planes. Amygdules and varioles in chloritic schist display symmetrical pressure shadows and have well rounded to oblate shapes (Fig. 4B), suggesting weak to moderate flattening associated with this foliation. A steeply south-plunging lineation caused significant stretching of varioles and other volcanic textures (Fig. 4E). Late kink banding is locally developed in fine-grained, sheet-silicate–rich rock types. No significant map-scale folding appears to be related to this stage of deformation. Several northwest-trending, vertically dipping brittle faults transect all rock types (Fig. 4F).

Field evidence suggests that Doris strata are folded into a tight, shallowly north-plunging antiform (J.S. Gebert, unpub. rept., 1999). Facing indicators in Doris basalt are rare, but a distinct facing reversal is present in pillow basalt within the bounding, Mg-tholeiitic pillow basalt (Sherlock et al., 2003). The younging direction is based on the orientation of gas cavities in pillow basalt which, along the western shore of Doris lake, suggests a west-younging volcanic succession. Similar rocks on the east shore of Doris lake indicate an east-younging stratigraphic succession. The existence of this antiform is evident on a cross-section through Doris North (Fig. 3), where stratigraphic repetitions and the orientation of lithological contacts describe an antiformal shape with an axial plane that is parallel to the main S_2 fabric.

GOLD DEPOSITS

Gold mineralization at Doris North is associated with quartz veins accompanied by variably thick hydrothermal alteration envelopes. Three, approximately north-trending and near vertically dipping, gold-bearing quartz-vein systems are known in the Doris North area (Fig. 2). From west to east, these zones are the West Valley Wall veins, the Central vein, and the Lakeshore vein. The relatively flat-lying and shallowly north-plunging Hinge zone occurs where the Lakeshore and Central veins merge, resulting in a shallowly north-plunging 'fish-hook' geometry (Fig. 3). Mineralization of the West Valley Wall zone is hosted by strongly magnetic massive basalt, and is associated with a series of narrow (<30 cm) and discontinuous quartz veins clustered over a 1 to 2 m width. The Central vein is 70 m east of the West Valley Wall veins, at the westerly contact between vesicular-amygdaloidal basalt and gabbro. Surface exposures of the Central vein consist of a main, 30 cm wide, north-striking, vertically dipping quartz vein directly at the basalt-gabbro contact. The Lakeshore vein is 30 m east of the Central vein, outcropping on the northwest shore of Doris lake at the westerly contact between gabbro and amygdaloidal Fe-tholeiite pillow basalt. This steeply west-dipping vein averages 4 to 5 m in width and locally approaches 8 m.

Alteration

Gold mineralization is accompanied by pervasive hydrothermal alteration of basaltic and gabbroic wall rocks. Alteration zones flank quartz-vein systems and alteration intensity decreases away from mineralized zones. Wall-rock alteration is coeval with quartz-vein emplacement and, in areas away from intense alteration, distinct alteration haloes are present around narrow quartz veinlets (Fig. 5A). In general, alteration intensity and quartz-vein density correlate positively, and wider quartz veins have wider alteration haloes.

Two broadly defined zones of alteration have been recognized in outcrop and drill core: strongly and weakly altered zones (Fig. 5B, C). Strongly altered zones are proximal to quartz veins and are characterized by intense iron-dolomite, paragonite, sericite and quartz-flooded zones. Weathered exposures of strongly altered rocks are distinctly rust coloured and have a fissile texture, whereas fresh drill core is bleached grey to beige. Primary magnetism is destroyed in strongly altered rocks, but volcanic textures, such as pillows and varioles, are normally preserved. Gabbroic textures are also preserved in strong alteration, showing a speckled or spotted texture (Fig. 5D). The total width of strongly altered zones is variable, and ranges from 1 to 2 m at West Valley Wall, from 5 to 6 m at the Central vein, and from 10 to 20 m at the Lakeshore-Hinge vein (Fig. 3). Weakly altered zones are characterized by weak and sometimes cryptic carbonate (dolomite and/or calcite) alteration in basaltic rocks and a calcite+leucoxene (after magnetite) assemblage in gabbro. Weakly altered zones are typically twice the width of strongly altered zones.

Alteration zones are strongly foliated and fissile due to the regional S_2 fabric (Fig. 5C). High mica contents have made altered zones easily susceptible to fabric development, but amygdules and varioles within altered zones do not appear to have increased flattening or rotational features, implying no increase in strain intensity within these alteration zones.

Vein textures

Gold mineralization at the Central-Lakeshore-Hinge zones is hosted primarily within a single, relatively homogeneous white quartz vein (Fig. 6A). Vein contacts with surrounding wall rocks are sharp and generally straight, but both the Central vein and the Lakeshore vein can have an adjacent zone, several metres wide, that is characterized by abundant, narrow, white quartz veins and veinlets trending roughly parallel to the trend of the main vein (Fig. 6B). Quartz-vein density in these adjacent zones is variable and ranges from absent to 50%. Gold content in these vein systems is typically low (i.e. <1 g/t Au).

Vein textures range from massive and milky white to highly brecciated and rich in altered, angular wall-rock fragments (Fig. 6C). Medium- to coarse-grained dolomite grains

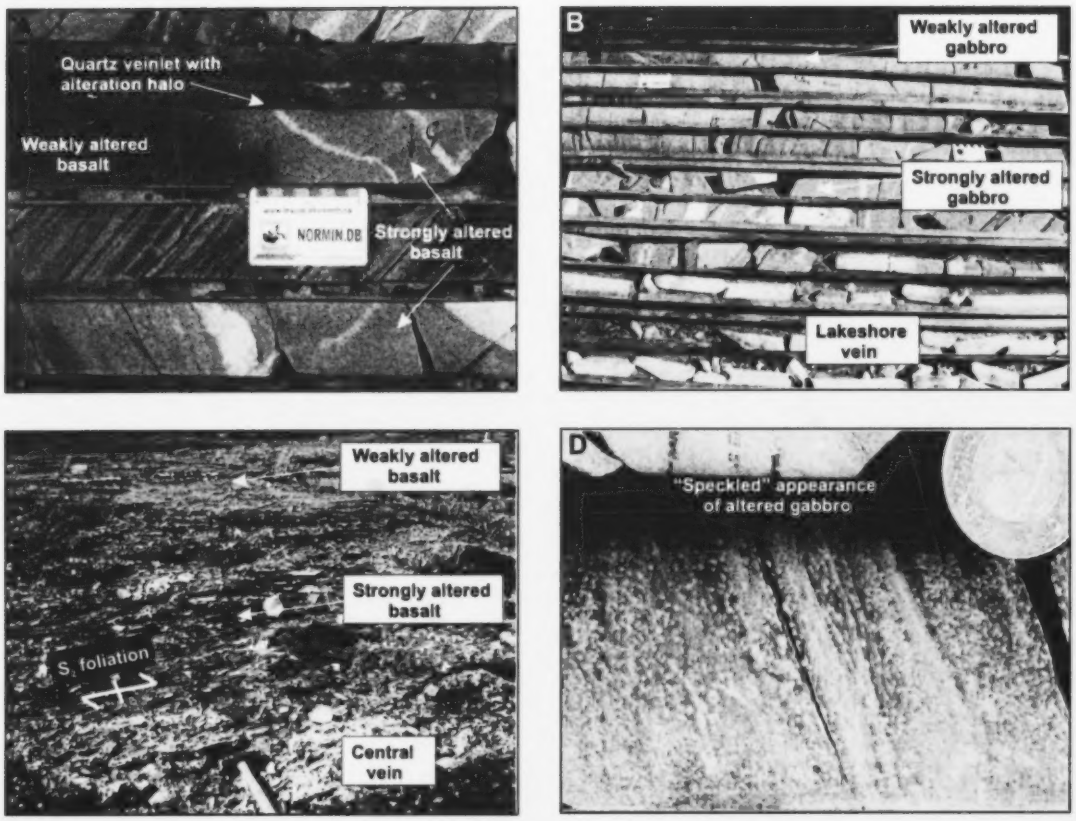


Figure 5. *Hydrothermal alteration:* ***A)*** *halo of strong iron dolomite and sericite around quartz veinlet; scale card (in centimetres) provided;* ***B)*** *progressively altered gabbroic rocks approaching Lakeshore vein; scale card (in centimetres) provided;* ***C)*** *progressively altered basaltic rocks near the central vein, looking west; hammer for scale;* ***D)*** *speckled appearance of strongly altered of gabbro.*

are common and are generally found near vein contacts with wall rocks. Altered wall-rock fragments are millimetre to centimetre scale in size and are most common near vein margins. Fine-grained and well formed pyrite is either disseminated in veins or forms concentrations within wall-rock fragments (Fig. 6C). Variable amounts of narrow sericite, chlorite and/or tourmaline 'septa' are irregularly distributed throughout veins and generally trend parallel to vein margins (Fig. 6D). Where abundant, septa can locally form a dense, web-like pattern. Centimetre-scale, relatively flat, 'ladder-like' white quartz veins crosscut septa-bearing veins and do not appear to contain gold (Fig. 6D).

Visible gold is present in veins, where it ranges from individual pinprick-sized areas to larger centimetre-scale patches containing numerous fine gold grains. Gold is commonly seen along or near septa-rich parts of veins (Fig. 6E), but isolated gold occurrences in otherwise 'bull' parts of veins are not unusual. Economic widths of gold mineralization (typically >15 g/t Au) commonly occur near vein and wall-rock contact zones; however, significant mineralized intersections are also present throughout the veins. Gold grades correlate well with the distribution of visible gold, but no obvious geological criteria have been identified that can predict the distribution of gold-rich and barren domains within individual veins.

TIMING CONSTRAINTS

The maximum timing of gold-bearing quartz-vein formation at Doris North is constrained by the presence of clasts of foliated and altered wall rocks within the veins (Fig. 6F). Because orientations of foliation in each wall-rock fragment are different and random, fabric development and alteration must have occurred pre- to syn-veining. Since the alteration is a product of quartz veining (Fig. 5A) and locally the veins are strongly deformed in the alteration zones (Central vein) and brecciated along vein–wall-rock contacts, this suggests an overlap in the timing of alteration, deformation, and quartz veining. Well formed and weakly altered pyrite commonly grew within fragments, and coarse iron-dolomite grains overgrew

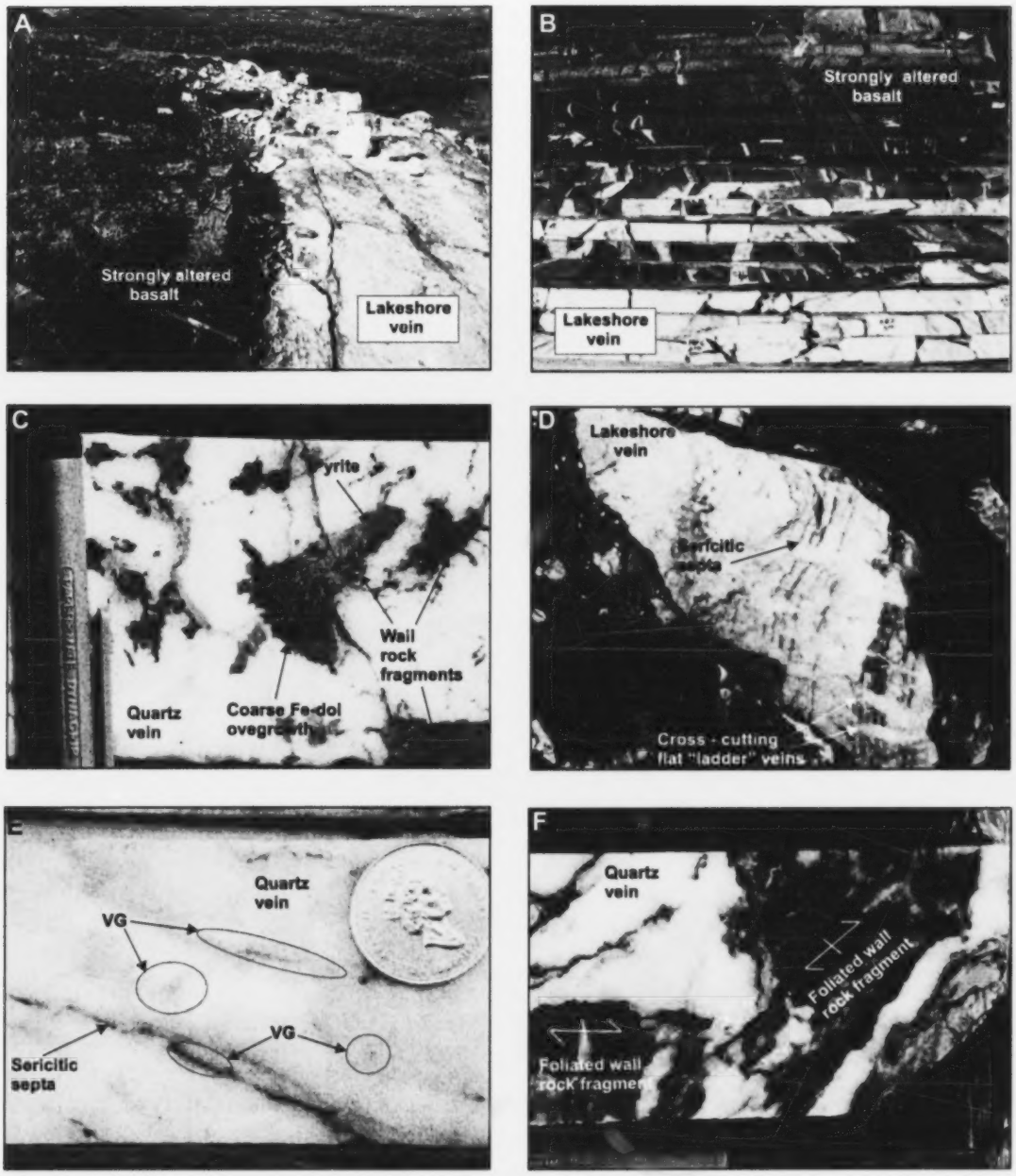
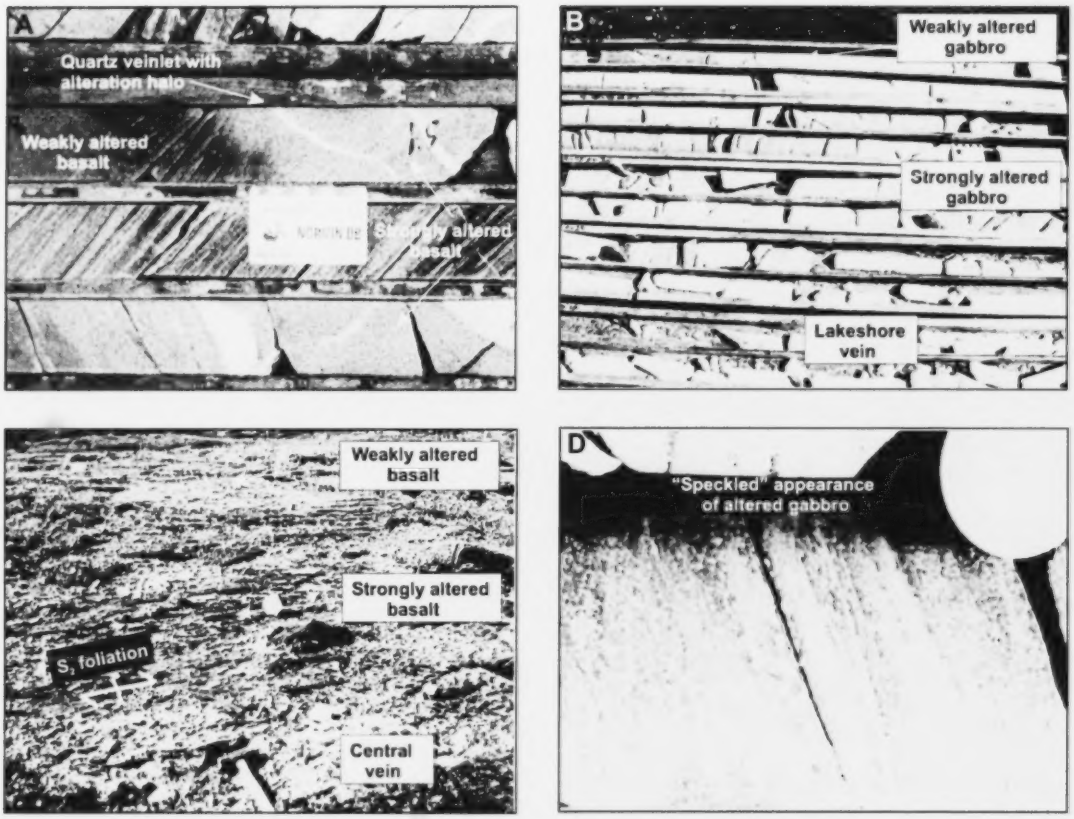


Figure 6. *Mineralized quartz veins:* ***A)*** *surface view looking north from the Lakeshore vein; hammer for scale;* ***B)*** *zone of abundant quartz veinlets directly above intersection of Lakeshore vein; hammer for scale;* ***C)*** *weakly deformed coarse iron dolomite and pyrite overprinting already altered wall-rock fragment; pen for scale;* ***D)*** *surface exposure of Lakeshore vein; hammer for scale;* ***E)*** *high-grade quartz vein with abundant visible gold (VG), Hinge zone; coin for scale;* ***F)*** *foliated wall-rock fragments in gold-bearing quartz vein; note that foliations are at variable orientations; pen for scale.*



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The maximum timing of gold-bearing quartz-vein formation at Doris North is constrained by the presence of clasts of foliated and altered wall rocks within the veins (Fig. 6F). Because orientations of foliation in each wall-rock fragment are different and random, fabric development and alteration must have occurred pre- to syn-veining. Since the alteration is a product of quartz veining (Fig. 5A) and locally the veins are strongly deformed in the alteration zones (Central vein) and brecciated along vein–wall-rock contacts, this suggests an overlap in the timing of alteration, deformation, and quartz veining. Well formed and weakly altered pyrite commonly grew within fragments, and coarse iron-dolomite grains overgrew

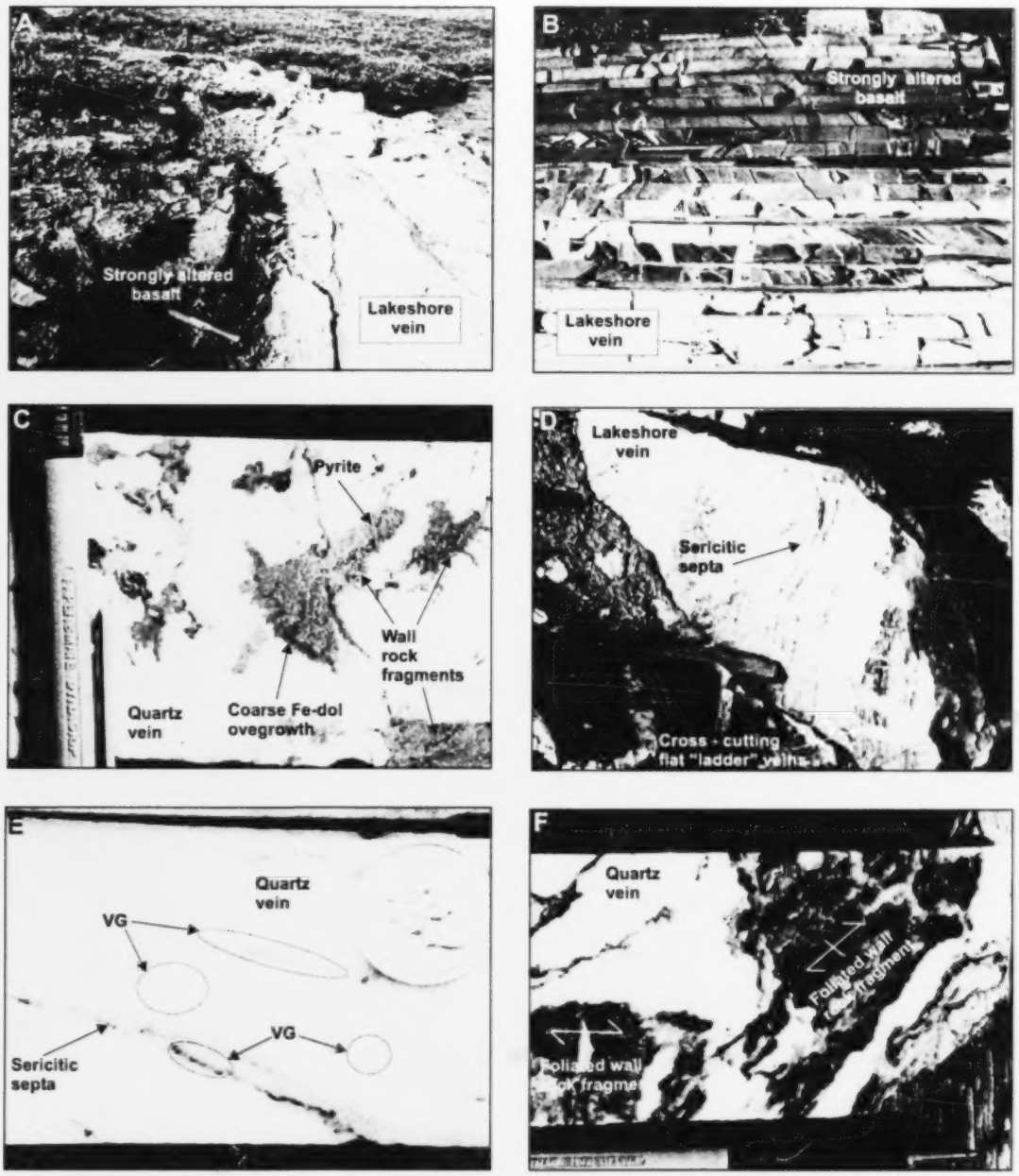

Figure 6. *Mineralized quartz veins: **A)** surface view looking north from the Lakeshore vein, hammer for scale; **B)** zone of abundant quartz veinlets directly above intersection of Lakeshore vein, hammer for scale; **C)** weakly deformed coarse iron dolomite and pyrite overprinting already altered wall-rock fragment, pen for scale; **D)** surface exposure of Lakeshore vein, hammer for scale; **E)** high-grade quartz vein with abundant visible gold (VG), Hinge zone, coin for scale; **F)** foliated wall-rock fragments in gold-bearing quartz vein, note that foliations are at variable orientations, pen for scale.*

fine-grained dolomitized wall-rock fragments (Fig. 6C). Pyrite and coarse iron dolomite are only weakly deformed, since they lack the pressure shadows that are characteristic of amygdules and varioles (Fig. 4B). These observations are consistent with gold-bearing quartz-vein emplacement during later phases of progressive alteration coeval with regional D_2 deformation.

The timing of vein formation with respect to folding of the stratigraphic pile remains somewhat equivocal. The overall geometry of the vein systems closely mimics fold orientations mapped in basaltic and gabbroic rocks. Similarly, the wall-rock septa, which form parallel to a propagating quartz vein (Robert and Poulsen, 2001), are nearly vertical in the Lakeshore vein (Fig. 6D) but swing to a subhorizontal orientation in the flat-lying Hinge zone. These geometries can be explained by vein development in dilational sites created during folding in a scenario analogous to a saddle reef, during a progressive D_2 event. This accounts for the occurrence of foliated and altered wall-rock clasts in veins and weakly deformed sulphide grains associated with mineralization.

SUMMARY

Gold deposits at Doris North are hosted in a distinctive mafic volcanic package referred to as the Doris Suite basalt. These rocks consist of a conformable package of variably magnetic, vesicular-amygdaloidal, massive and pillowed Fe-tholeiitic basalt and gabbro. Drill-core logging and detailed field mapping have demonstrated that these units can be traced and placed in a stratigraphic framework. Stratigraphy is generally north-striking and appears to be folded into a tight, shallow, north-plunging antiform. Facing reversals in enclosing basalt, stratigraphic repetitions, and overall geometry define the fold structure.

Mineralization is associated with white quartz veins accompanied by variably thick hydrothermal alteration zones. Three north-trending and nearly vertically dipping, gold-bearing quartz-vein systems at Doris North are the West Valley Wall, Central, and Lakeshore veins. The relatively flat-lying and shallowly north-plunging Hinge zone is where the Lakeshore and Central veins merge. Native gold is observed within quartz veins and is commonly associated with sericite or tourmaline-rich septa, but is also observed in 'bull' white parts of veins. Alteration zones associated with quartz veins comprise a proximal zone rich in iron-dolomite, sericite, and paragonite alteration, flanked by a distal or weaker zone of iron dolomite±calcite.

The geometry of the Lakeshore-Central-Hinge zones mimics the fold patterns in the host stratigraphy. Textural evidence suggests that vein formation might have propagated along a dilational zone as fold structures developed during a progressive D_2 event.

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